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Lowering the Transportation and On Site Labour Costs - Some Proposals

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LOWERING THE TRANSPORTATION AND ON SITE LABOUR COSTS - SOME PROPOSALS

by

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It is a well known fact that the problem of housing, today, is one of the main factors in creating social unrest and that its negative influence on the society is constantly increasing.

More than 180 million families in the world lack a simple shelter, 2/3 of the world's population has no piped water. Out of 91 developing countries 52 have a per capita annual income of less than $100, 23 between $100 and $200, 16 between $200 and $300. "A supply of housing services at a reasonable cost is a factor of great social importance." (1)

Approximately 180,000 new people are added to the population of the world every day; with the present rate of growth of the world's population and the lag existing between the large demand and the small supply, this problem will take a very critical or even tragic aspect before the end of this decade if something is not done to improve its serious condition in a permanent and effective way.

"Only the developed techniques of production and organization, adapted to the particular condition of the developing countries can give rise to hope that a situation that continually worsens can be effectively improved, by setting it in the framework of scientific and technical progress of a world whose quantitative and qualitative needs grow unceasingly." (2)

In the light of the above considerations, the question of low cost housing on its world wide scale will mean providing permanent accommodation responding to the basic needs of the great majority of world's low income population, which are:

a) permanent shelter against outside agents, and providing privacy;
b) minimum of comfort and services;
c) good quality at low cost.

When we consider the prefabricated or industrialized building as an answer to the problem of housing, we can include other desirable requirements:

- Ease of erection and assembly (not requiring specialised labour).
- Possibility of expansion when the need arises.
- Demountable or easily movable.

Each of these factors should be considered separately to arrive closer to the solution.

COST FACTORS

The reduction of cost, which is, and will remain one of the most important problems of housing, is dependent on several factors. It is necessary to bear in mind that a house is not a single unit costing several thousand dollars but rather a sum of several sub-units of a few hundred dollars each, or even, several hundred parts each costing $10. Efforts should be made to bring down costs of each of these sub-units without damaging the quality of the house, instead of eliminating parts or using low quality material and, therefore, creating substandard housing.

A breakdown of costs of a single family detached house, or condominium housing (both in conventional and prefabricated housing) shows that out of the total cost of production of a housing unit an average of 45% is spent on the "enclosure" of the house, 25% on the mechanical services and 30% on the finishes. (3) If we separate labour costs from gross material costs, approximately 40 to 50% of the factory production cost of the unit is spent on gross materials. (3) The net material cost is less than half this figure (4) or less than a quarter of the total cost of the construction. Other elements make the other three-fourths. Unfortunately, the tendency of the builders today is mostly to cut down on the materials, creating substandard, low-quality housing instead of looking at the other areas of cost for possible savings.

An average cost breakdown of prefabricated sectional homes based on 20 sample units of 24' X 36' (3 bedroom) delivered to various sites within the province of Quebec (35 miles to 630 miles distance), was studied and compared to costs of other conventional and industrially produced houses. (5) It was found that once these houses reached the distributor and were eventually ready for sale to the user, the initial factory cost increased between 50% and 250%, depending on the type and location of the development, the land improvements, services, financing, and of course different profit factors. Table A shows this gradual increase in 3 main stages.

Although the processus of marketing may vary in different areas, the table with slight variations, should reflect the situation everywhere.

There are three distinct cost areas in this table: the first is costs which are dependent on the materials, labour, and methodology of production, which can hardly be changed except through optimization of management and better organisation of the factory, direct purchasing, rapid turn over of materials, higher efficiency of labour through incentives such as profit sharing, Standardization and Modular Coordination etc. The second area is comprised of costs which are out of the control of the producer and designer; they require government intervention in controlling land speculation, profit margins of different agents or agencies, reduction and stabilisation of the rate of interest, creating financing facilities, providing stimulus to the industry, simplifying or unifying the codes, etc. The third area includes costs which may be eliminated or reduced through architectural research and studies as they constitute the prerequisites of the "System" used, and can vary with the variation of the "Hardware", without having any or little influence on the final utilization or quality of the space sold to the user. They do not affect the so called "software".

Our research (6) at the school of architecture (Laval University) was based mainly in studying this area, and particularly in finding ways and means of reducing the costs of transportation and the on-site labour costs, while taking into consideration all other requisites of a housing system adaptable to the needs of a majority of the people in low and medium income brackets. Table B shows the increase in costs of transportation and the site labour cost, taking into consideration the displacement cost of labour, as a result of which the total installation costs make an exponential curve above the 300 miles haul.

There has been much discussion on the advantages or disadvantages of box systems compared to panel systems. It is not the purpose of this paper to enter such a discussion, but only to evaluate the two systems in the light of the above mentioned factors.

An average house built in panel system is composed of 16 to 30 sections including the mechanical sub-systems. On the average 3 to 5 semi-trailer travels are required for the delivery of these components to the construction site (7); the same house built in the box system will require 1 to 2 travels. The erection of the panel system would take between 70 and 160 man hours while the box system will be installed in 20 to 40 man hours.

Except for the light panel system and some wooden sectional houses, all systems require the use of some handling equipment and cranes, especially when the system goes high-rise, in which case there is not a large difference between costs of equipment in various systems.

It has been suggested that the location of a prefabrication plant should be at the center of a populated area and covering a radius of 300 to 600 miles. (8) It is evident that the cost of transportation of components and labour becomes of high incidence on the total cost of the unit when carried this far, and takes monumental proportions when carried even further away, to reach the less populated areas, where generally the poorer strata of society live.

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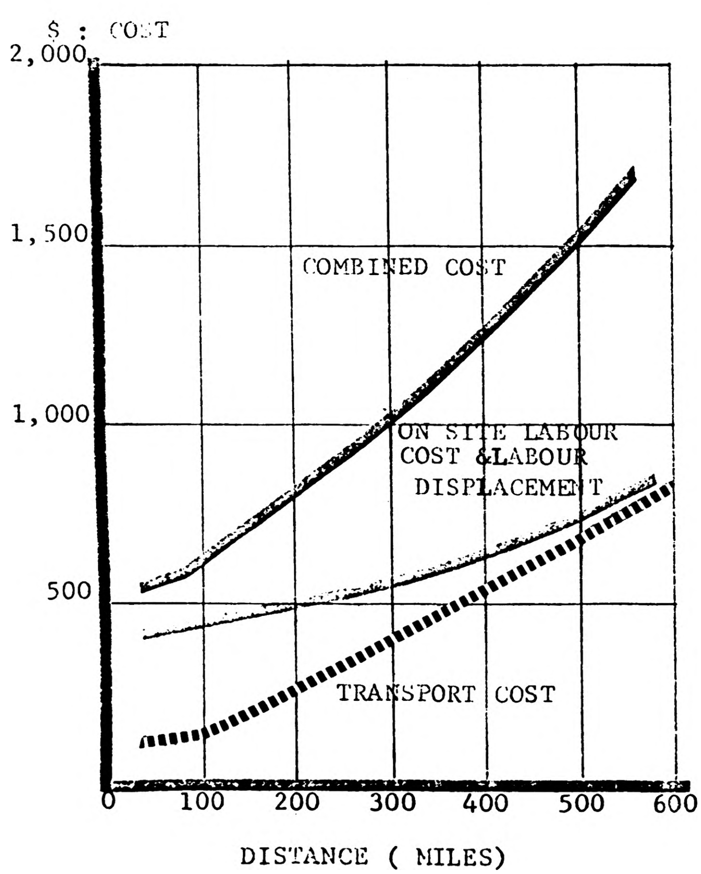
TABLE A

COST BREAKDOWN OF A 3 BEDROOM - 960 S.F. UNIT
BASED ON STUDY OF 20 SAMPLE HOUSES PREFABRICATED
AND DISTRIBUTED ACROSS QUEBEC PROVINCE

BUILDING MATERIALS	FACTORY LABOUR	TOTAL COST OF PREFAB. HOUSE	TRANSPORT COST	TRANSPORT OF LABOUR	ON SITE LABOUR COST	COST OF A DELIVERED HOUSE	MANUFACTURERS OVERHEAD	MANUFACTURERS PROFIT	TOTAL COST OF A DELIVERED HOUSE	LAND COST	SITE DEVELOPMENT	COST OF THE INSTALLED HOUSE	DISTRIBUTORS OVERHEAD	DISTRIBUTORS PROFIT	TOTAL COST OF THE INSTALLED HOUSE
71%	29%	100%													
62%	25%	87%	4%	2.4%	5.7%	100%									
47%	19%	66%	3%	2%	4%	75%	15%	10%	100%						
34%	14%	48.1%	2.2%	1.3%	3.1%	54%	11%	7.3%	73%	12%	15%	100%			
30.8%	12.5%	43.3%	2%	1.2%	2.8%	49.3%	9.8%	6.6%	65.7%	10.5%	14%	90.2%	2.8%	7%	100%

TABLE B

INCREASE IN INSTALLATION COSTS OF PREFABRICATED HOUSE RELATIVE TO DISTANCE.



One of the basic reasons for establishing this radius has been in fact the economy of truck transportation, beyond which other means of transportation, like the railroads become more economical (but most systems have not been designed to take advantage of it).

On the other hand, if these considerations remain valid in the more industrailized nations of the world which possess an efficient network of roads and railways (within the United States, 85 per cent of the population lives along the major routeways), the problem takes an entirely different outlook in the developing countries, where because of the lack of such services, the factor of transportation might well be the highest factor influencing the cost of the factory-built housing. It is also unrealistic to assume that in these countries prefabrication plants should cover a smaller radius market, as the urban geography of these countries is of a rural, and therefore, scattered nature. Moreover the high initial investment costs of such plants in these countries makes it economically unfeasible.

It is also necessary to bear in mind that in all cases, it will be unavoidable to exceed the 600 miles radius, to reach the smaller populated areas, or to provide shelter to the disaster-stricken places, to build emergency housing, or to answer the housing need in the North, etc. Burnham Kelley explains the industry's reasons for the adoption of the 300 miles radius, "there are no overall patterns of proximity to raw materials... Therefore, there is an advantage to be closer to the market than the raw materials... although house packages have been shipped as far as 1,000 miles and beyond, the vast majority were not transported more than 300 miles for reasons of cost... we might thus expect that prefabricators were serving local or regional markets rather than national ones and that they were located close to where houses were erected ...". (9)

There is no doubt that this kind of self-imposed limitation, while valid for the small industry, becomes unacceptable when the world wide problems of prefabrication and housing are envisaged. Today, the housing industry needs the large scale involvement of governments and private enterprise in creating high volume production factories building housing units to be marketed to all areas where such capabilities are lacking; we need a VW or Fiat of the housing industry--and the transportation "problem" should not hamper the industry from developing such an equivalent.

The question of transportation is not completely covered if we do not deal with the factors of weight and volume. Heavy components require special handling equipment; they undergo different stresses during the transportation resulting in cracking of walls etc.; they require more site preparation and elimination of all vegetation close to the site; are extremely difficult to place on inclined terrain, etc. Altogether "shipping costs limit the size of the package... Big components are so expensive to handle that less finished panels usually make more sense today... and tomorrow a still smaller and less finished package may prove the most practical of all". (10)

Briefly our research showed the following points,

- The limit of 300 miles transportation is a self imposed limit which can hamper the development of industrialized housing.
- Low cost housing should be so developed that little or no on-site labour is required for its erection.
- Prefabricators should use the present day technology to their advantage instead of continuing to build "conventional housing in a factory".
- Advanced transportation logistics should be adopted in the service of prefabrication technology rather than custom building services to answer the need of the "System".
- New "Prefabrication Systems" are required to utilize the maximum potentialities of industrialization in creating simple, versatile components.

On the basis of the above conclusions, and taking into consideration the minimum requirements of the low cost housing, a program of work was established and some architectural projects were developed, two of which are presented in this paper.

CONTAINERIZATION

"Today there are forces acting on carriers which will in relatively brief time effect a much higher degree of coordination than has been true in the past. The most important of these forces is the growth in use of equipment that provides intermodal compatibility". (11)

"The intermodal system of containerization, utilization of freight commodities in standardized van-size cargo capsules which can be interchanged between transportation modes with ease can be cited as the prime example of coordinated, automated transportation". (12) Between 1960 and 1967, the inventory of containers increased at an annual rate of 35%.

"The enormous expenditures, now estimated at over $1 billion, made during the past few years, (in containerization) particularly in the marine trade, are laying the ground work for a world wide land-sea-air transportation complex the impact of which is already being felt in all modes of transportation..." (13)

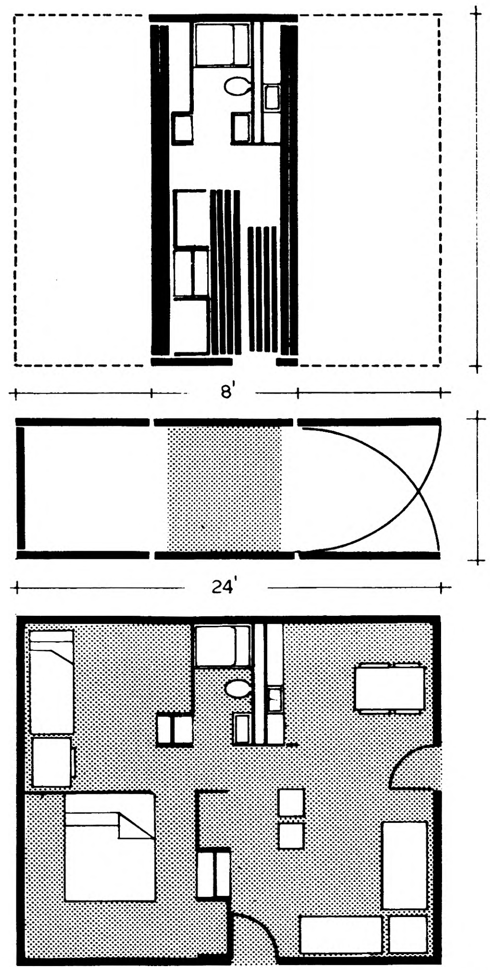
It is the author's belief that the housing industry should take advantage of this already "revolutionary" and coordinated system of transport to expand its field of interest and to reach farther at less cost.

Regular containers come in 4 different sizes, 8' wide X 8' high by 10', 20', 30', or 40' long. Physical dimensions of a 20' container unit were studied, and through the application of some simple principles of kinetic architecture and close packing methods, a "System" was developed to contain all the elements forming a house 3 or 4 times larger than the initial volume of the container.

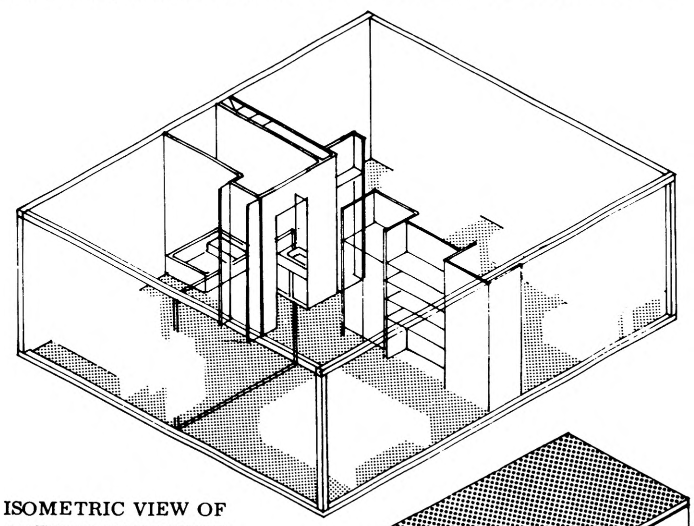
The system has enormous possiblities and our studies, which are being continued, show that a variety of types of housing can be made within the container system, practically adaptable to every kind of need in the low cost housing market.

A sample model of a container conceived to answer the needs of the North American market, built in Balloon frame structure and stress skin panels, has been produced to show one of the possibilities of the system. (Figures 1 to 8). In this particular example, the complete bathroom and the fixed elements of the kitchen are permanently installed on the two sides of a mechanical wall which can carry the heating or air condition unit. There is also enough room in the closed container to add kitchen equipments, furniture, etc. The sample is aiming to show some of the principles involved and not necessarily the method of fabrication, the materials, or the treatment which could vary according to the available resources, or the formation of the industry. The housing containers can be installed in less than 3 hours, by two unskilled men, with no need to any special tools or equipment. The containers are stackable together (or on each other).

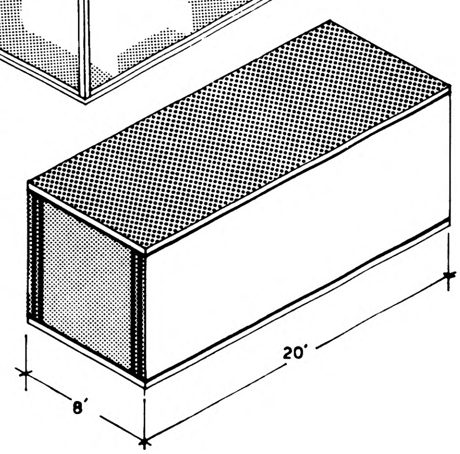
Because of the relatively small size of the exterior wall panels



Schematic plans and section of Packed and opened container House



ISOMETRIC VIEW OF OPENED CONTAINER



PACKED CONTAINER READY TO SHIP

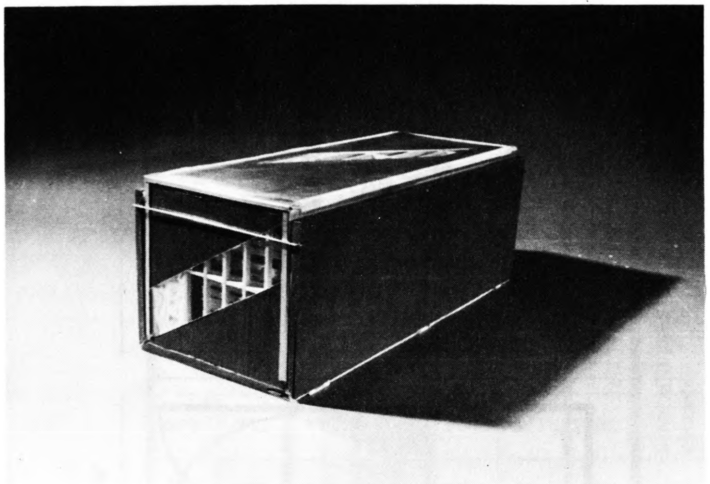


Fig. 1.

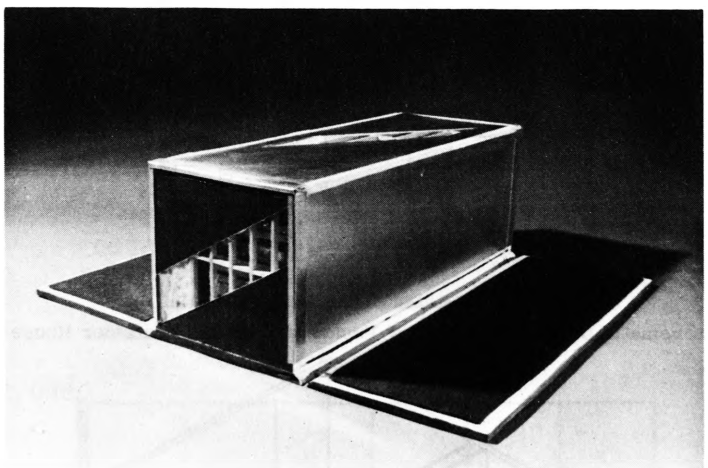


Fig. 2.

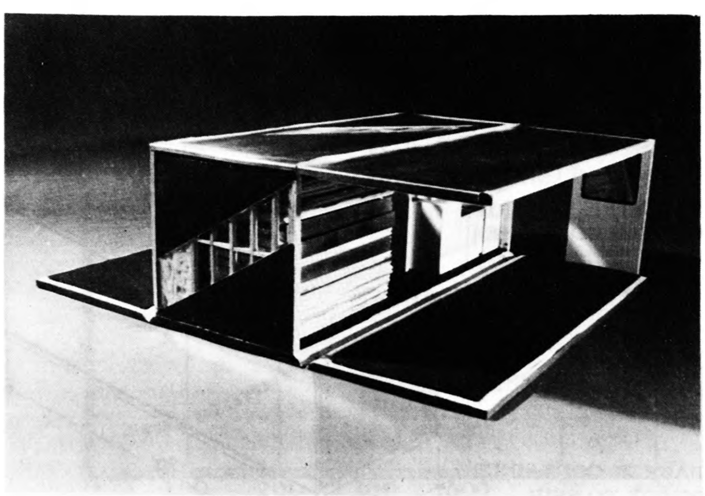


Fig. 3.

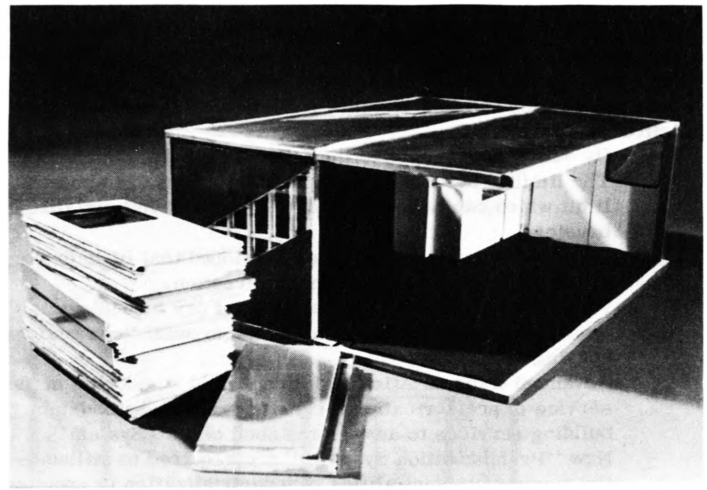


Fig. 4.

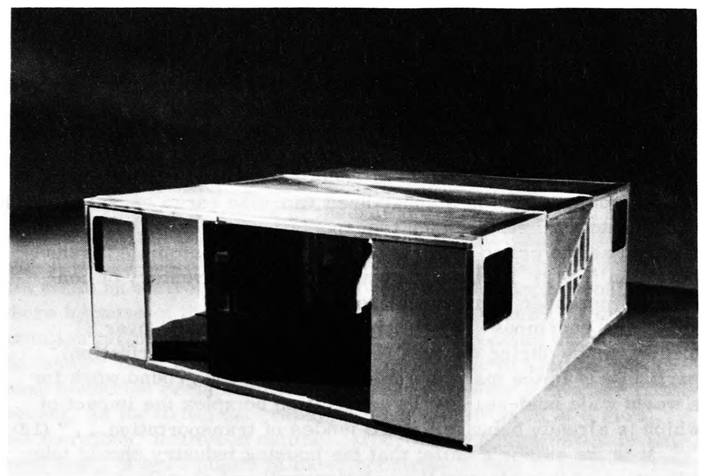


Fig. 5.

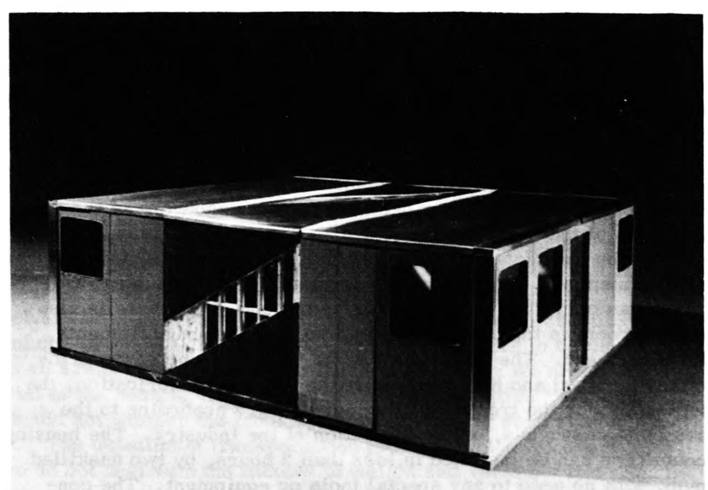


Fig. 6.

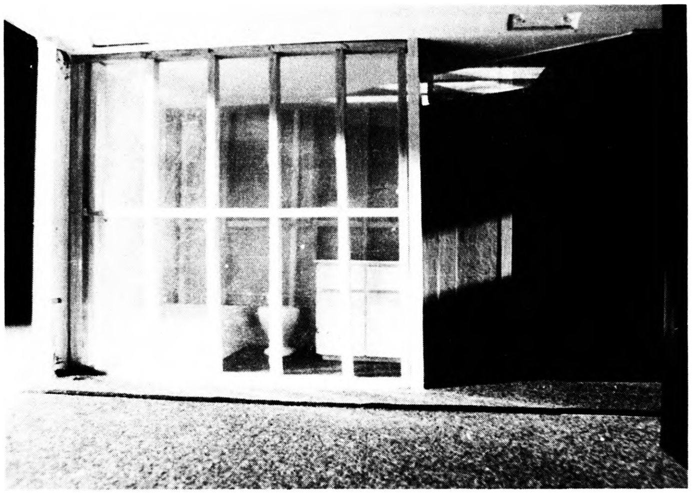


Fig. 7. Interior views of container

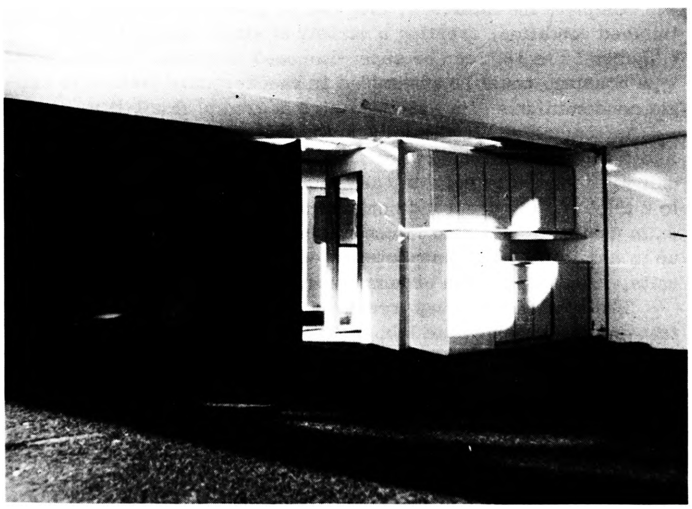


Fig. 8. Interior views of container

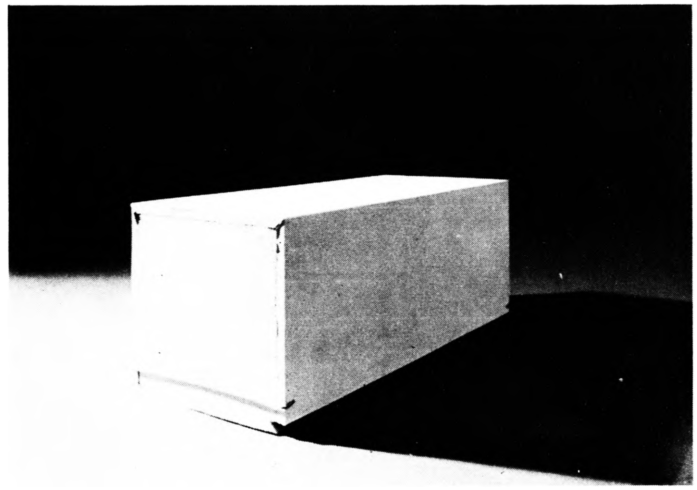


Fig. 9. Emergency type container housing 4 families

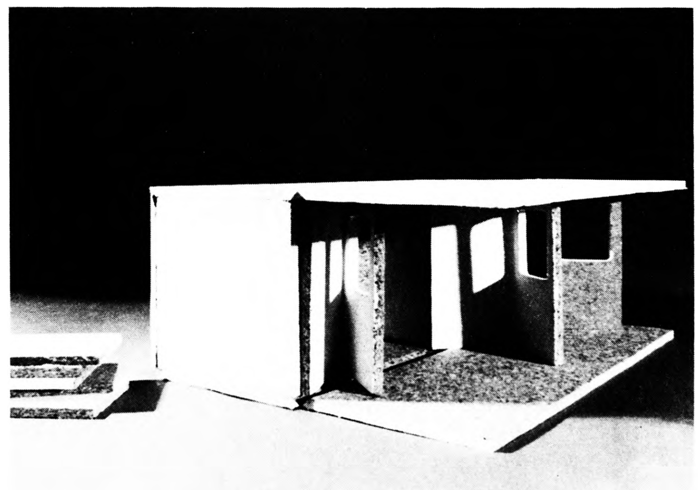


Fig. 10. Emergency type container housing 4 families

the owner can practically design his own house. The interior is also completely flexible, as the opened container offers an open space of 400 sq. ft. which can be arranged according to the user's need, with movable partition/closet walls.

Figures 9 to 12 show a much simpler application of the same type of container which can be used for emergency purposes, in disaster areas, or contingency housing. A similar container can house up to 4 families together, offering each 120 sq. ft. floor area.

Furthermore, it would be worthwhile to note that although our models show two 20' containers developed, we have studied the development of other container sizes into housing and they proved to be as advantageous; the 30' container will create a 3-4 bedroom, 720 sq. ft. house; the 40' one creates a 4-5 bedroom 960 sq. ft. house and the 10' container a comfortable 1 bedroom, bachelor apt. or student housing.

One additional asset of these containers is that they are easily demountable and transportable.

Of course the major advantage of the system would be in its transportation economy which as shown in (Table C) not only is cheaper on short distances because of the compactness and the standardised size, it becomes extremely economical when transported overseas. (14)

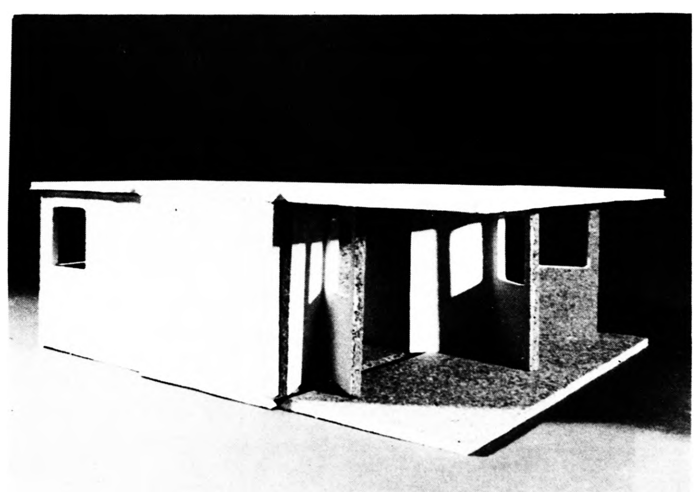


Fig. 11. Emergency type container housing 4 families

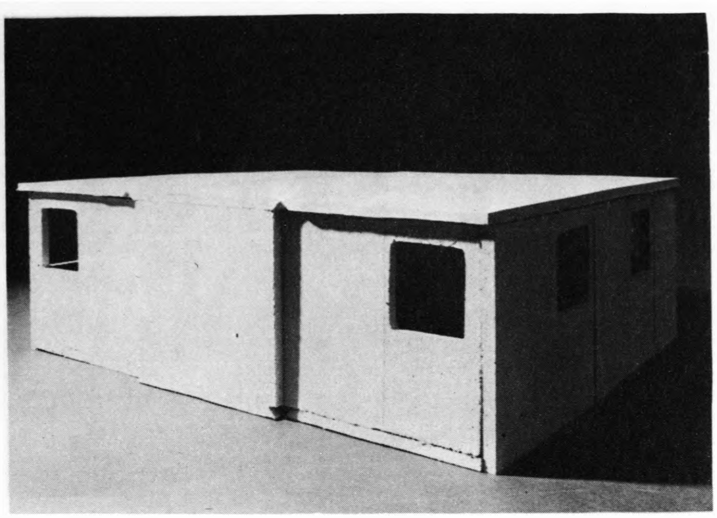
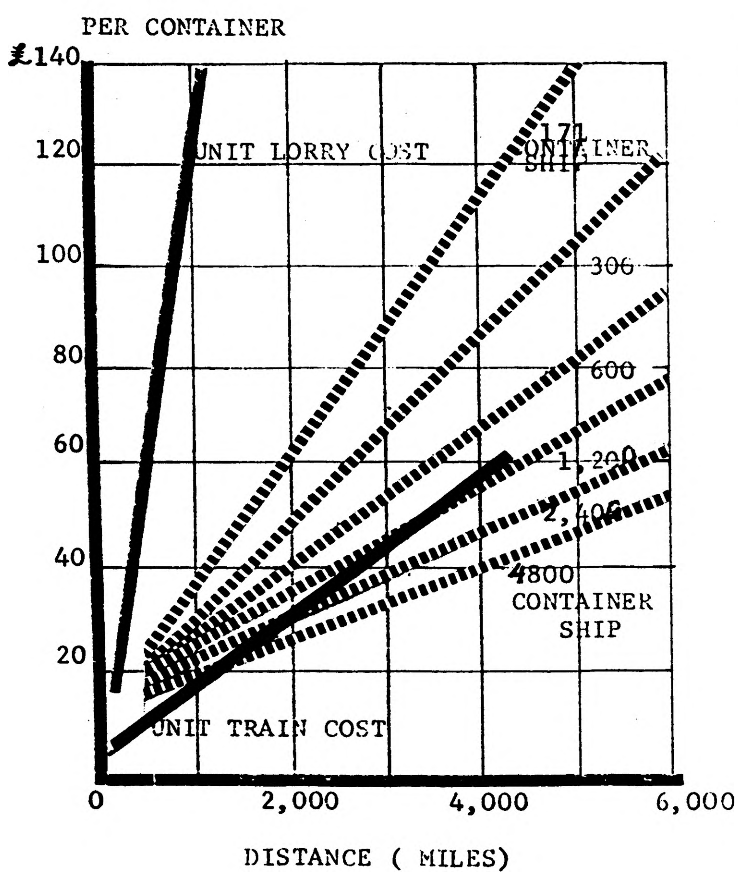


Fig. 12. Emergency type container housing 4 families

TABLE C

COST COMPARISON CHART OF TRANSPORTATION OF CONTAINERS. (14)



"TROUGH" SYSTEM

The second project is also aiming at the optimization of transport, this time through introduction of a new element which makes the floors, walls and ceilings of the housing unit, while being stackable for transportation purposes.

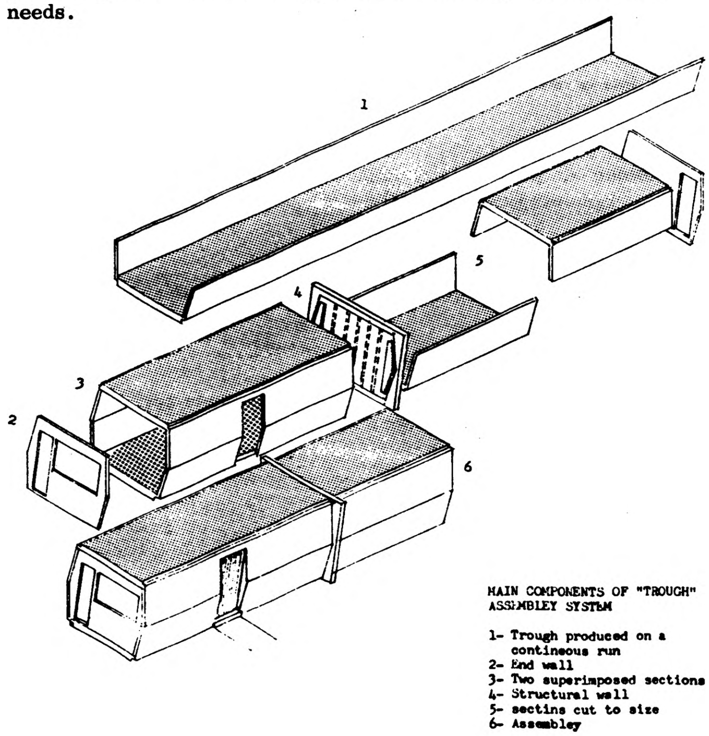
The system is composed of basically two elements, a "trough" made in the shape of an open "U", 12'.0" wide and 4'.6" high, and a cross wall 12' wide - 9' high. The open angle on the "trough" allows stacking of up to 8 sections together for the transportation purposes. Two "U"s superimposed create a living unit. (The joint between "troughs" being horizontal is easily sealed). These living units could be stacked together in a checker board fashion, creating a great economy in space and avoiding repetition of walls, ceiling and floor. Vertical cross walls carry the loads so that the "U" sections remain standard as they are always supporting standard loads.

One of the most interesting aspects of this system is that the "troughs" could be produced on a continuous run, as an extrusion; they can be moulded, poured, or be built in stud wall Balloon framing etc., and cut to the size required by the user. The 12' width is to comply with major road restrictions, but narrower or wider sections can be produced on the same production line and transported to the site without infringing the highway restrictions.

Another interesting aspect of the system is that the "U" troughs can be sold unfinished in small sections to the user who can complete the interiors; they can be produced and sold in finished condition, creating a variety of single family houses (Figures 13 to 18); can be super-imposed to produce mobile home type housing, could be assembled in checkerboard fashion to create condominiums etc., giving a high degree of flexibility.

In conclusion, it should be noted that while in a panel system 3 to 5 trips are necessary for all the sections forming a family unit to be moved to the site, and in a box system the number is 1 to 2 trips, in the proposed containerized system 2 to 3 housing units can be transported in one trip and in the "trough" system up to 8 units can be transported in one trip creating 4 to 6 housing units, resulting in high economies in transportation.

The combined savings resulting from the reduction of costs of transport and the on-site labour, (resulting from the simplicity of erection) will allow the Prefabrication Industry to reach the lower income families while providing them good quality at low cost, permanent and private shelter and the minimum of services and comfort plus offering flexibilities like personalization, add-on possibility and demountability, therefore satisfying their basic needs.



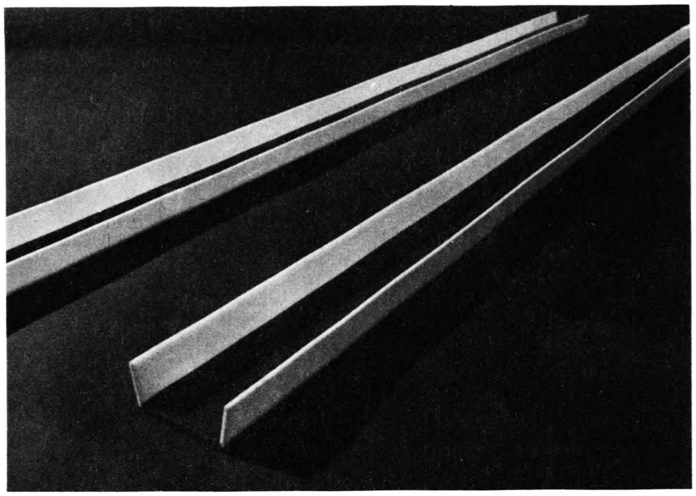


Fig. 13. Trough System components

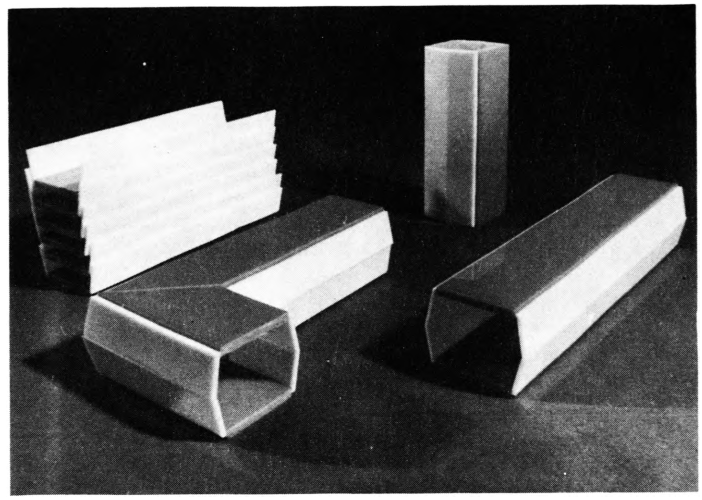


Fig. 14. Trough System components

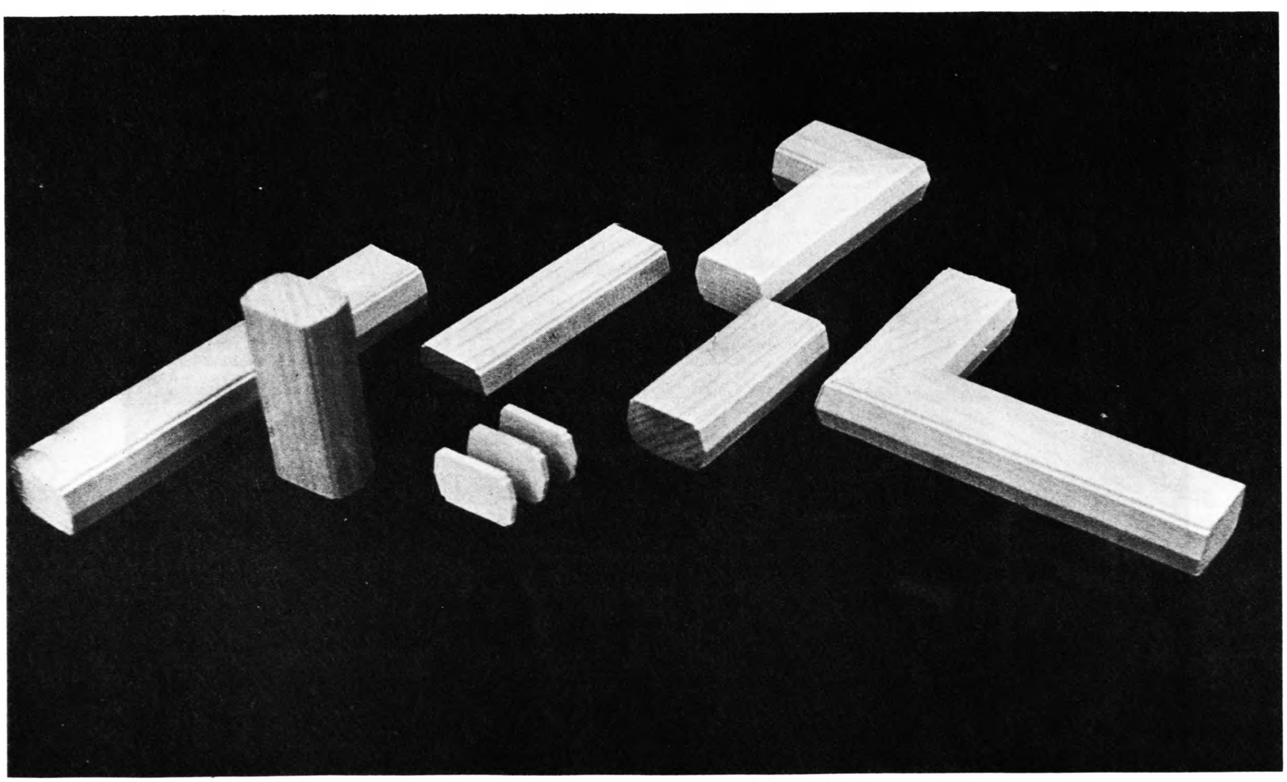


Fig. 15. Trough System components

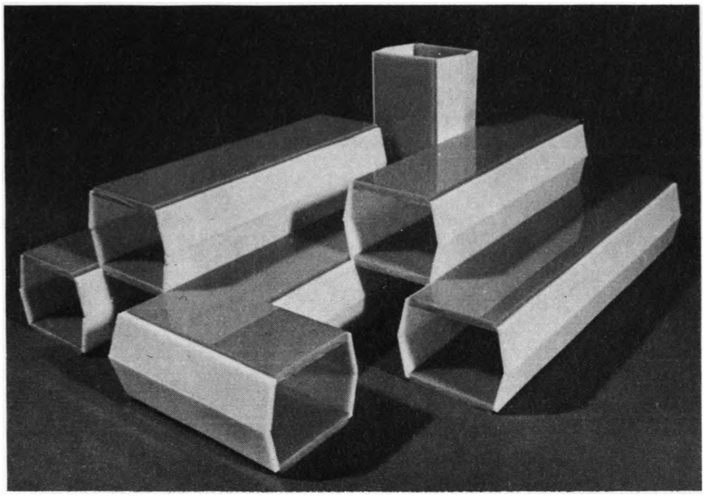


Fig. 16. Trough system, Three possible compositions.

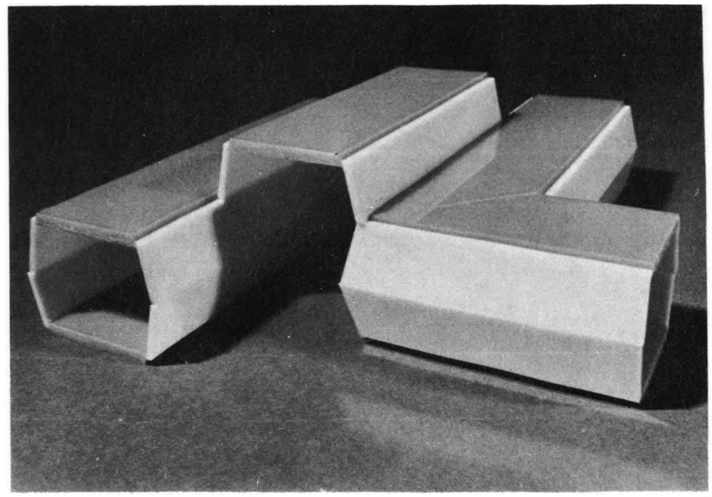


Fig. 17. Trough system, Three possible compositions.

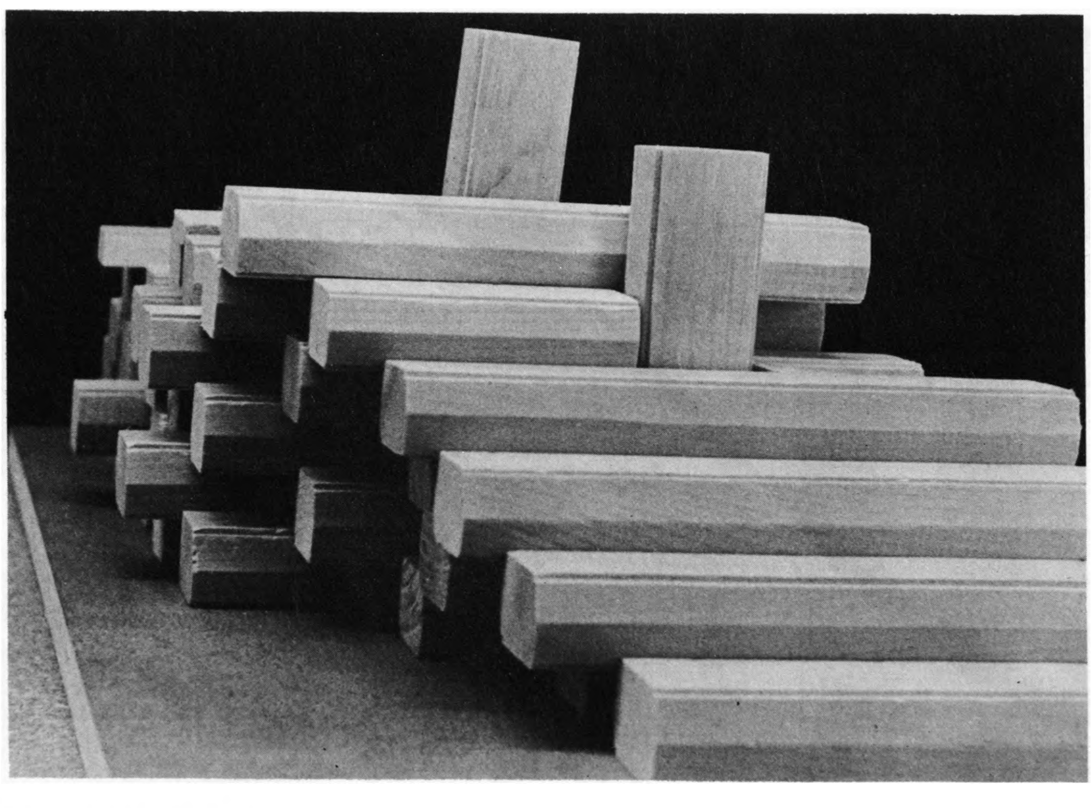


Fig. 18. Trough system, Three possible compositions.

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